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Two-mode Networks and the Interlocking World City Network Model: a Reply to Neal

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1. Introduction

In a recent paper published in *Geographical Analysis*, Neal (2011) presents a critical discussion of Taylor's (2001) interlocking world city network (IWCN) model. He argues that networks produced by the IWCN model are structurally pre-determined, and reveals some practical implications of this 'structural determinism.' Neal's critical reading of the IWCN model is refreshing, given that a review of the assumptions underlying the widely applied IWCN model has long been overdue. However, his critique tends to conflate problems associated with the analysis of two-mode networks with problems associated with the IWCN model *per se*.

We begin with a brief introduction to two-mode networks and the position of Taylor's IWCN approach within this context. We then consecutively review Neal's 'five structurally determined features' of the IWCN model, and conclude by reviewing implications for quantitative research based on the IWCN model.

2. Two-mode networks and the world city network

In the social network analysis (SNA) literature, a two-mode network refers to networks consisting of two disjoint sets of nodes, whereby the primary data connects nodes of both sets. In principle, two one-mode networks can be projected from a two-mode dataset. The projection function can take different forms, and can be used for different purposes. In some cases, two-mode networks are explicitly collected as an intermediate step to be collapsed into a single one-mode dataset. In other cases, without a sound conceptual motive for concentrating on one type of node, the duality of two-mode networks suggests

no reason to favour either of the two one-mode networks (Borgatti and Everett 1997).

The key point here is that the IWCN model clearly represents a two-mode network consisting of two disjoint sets of nodes (cities and firms), whereby the primary data consists of links connecting nodes of the different sets (the presence of firms in cities). Based on this information, in principle, city-to-city *and* firm-to-firm one-mode networks are possible to obtain and analyse (Neal 2008).

3. Structurally determined basic network structures

The first two structurally determined features identified in Neal (2011) are: (1) the resulting WCN cannot have a ring structure if the number of cities (N_{city}) is greater than or equal to the number of firms (N_{firm}); and, (2) the resulting WCN cannot have a star or chain structure if the number of cities minus one ($N_{\text{city}}-1$) is greater than or equal to the number of firms (N_{firm}).

Although the initial dataset used by Taylor (315 cities x 100 firms), as well as other datasets using the same model, cannot produce an *overall* WCN with a global ring/star/chain structure, these datasets are capable of *revealing* such networks within the WCN at large: the data are able to produce *multiple* such ideal-typical structures in *smaller* sub-networks. A consensus seems to exist amongst WCN researchers that this network is a combination of various local, regional and transnational urban networks with very different structures. Consequently, all quantitative analyses of the WCN, although drawing on very

diverse datasets and methodologies, reveal the existence of multi-layered and geographically complex networks that bear no resemblance to these ideal-typical structures. The consensus about a complex WCN also suggests that the methodological ability to detect a ring/chain/star structure consisting of all cities might not be very important. However, we note that the IWCN also is unable to detect some non-ring/chain/star and more complex structures as well, and this detectability problem is associated with network conflation and practical viability of one-mode projections in general. Additionally, the pitfall of two-mode networks is that we always can find ‘structural determinism’ in one of the one-mode projections if both sets have a different number of nodes.

4. Structurally determined cliques

The next two structurally determined features identified in Neal (2011) focus on cliques (i.e., coherent sub-networks): (3) the WCN cannot contain more than N_{firm} cliques; and, (4) the smallest clique contains at least F_{min} cities, where F_{min} denotes the number of cities in which the smallest firm maintains an office. Again, however, these two features result from one-mode projections of two-mode networks in a general rather than the specific IWCN model.

From this perspective, the problem of the upper limit for the number of cliques can be reduced to the issue of the number of firms to be included in a dataset. This has been dealt with in the previous section, and we therefore confine ourselves to the problem of the smallest possible clique. In principle, the solution to this problem can be tackled by deliberately introducing ‘small firms’ into a dataset, or devising a randomised process to maintain the possibility of having

small firms with the overall aim of permitting the detection of smaller cliques if they exist. In our view, however, this is not very useful as an *empirical* move because it is counter to the *theoretical* underpinnings of WCN research, which focuses on the power wielded by *large multinational enterprises* (Alderson and Beckfield, 2004). In other words: good, theory-driven reasons exist for focusing on firms with sizable prowess (however defined).

Given this preceding context, Neal's point about the problem of the smallest possible clique is useful because it suggests that IWCN researchers should remove firm inclusion criteria focusing on the minimal number of offices in different cities (e.g., 15 cities in Taylor et al., 2002). Rather, the focus should be on selecting the *largest* firms in sectors under investigation, which has been conventional in studies of city-firm relations (Alderson and Beckfield, 2004). Thus, IWCN's inclusion criteria would contain less subjectivity, and let the smallest firm among the top firms (i.e., 'population characteristics' as Neal puts it), rather than researchers' idiosyncratic choices, determine the size of the smallest clique.

5. Structurally determined network density

The fifth structurally determined feature model identified in Neal (2011) is that 'the size of the largest firm in the firm location matrix (...) constrains the density of the derived network.' This is a problem associated with the major critiques of projections of two-mode networks into one-mode networks (Latapy et al. 2008), which include: (1) information loss due to compression of the two-mode network; and, (2) an inflation of linkages due to the inclusion of every possible

pairwise link. Therefore, the ways in which these problems can be tackled are logically in line with Neal's (2011) proposed remedies and the SNA literature in general (Zhou et al. 2007), which may be summarised as follows: (1) rescale the network density and connectivity to allow for theoretical boundaries; (2) adopt methods explicitly developed for analysing two-mode networks; and, (3) more carefully devise projection functions.

6. Conclusions

In this short commentary, we review Neal's critiques and attempt to clarify the real implications of the so-called 'structural determinism' of the IWCN model. We suggest that most structurally determined structures identified by Neal are general features of one-mode projections of two-mode networks, rather than a specific weakness of the IWCN model, and, therefore the WCN should be studied in the context of two-mode networks directly to use the IWCN as a full-fledged *network*.

More practically, we recommend that: (1) the most desirable situation is to have as many cities *and* firms as possible when analysing city-firm relations, but having more firms than cities is not necessary; and, (2) WCN researchers would reduce data collection subjectivity and structurally determined features by removing the inclusion criterion of the number of offices.

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